The Office of the Municipal Executive

Ghyanglekh Rural Municipality

Bagmati Province, Sindhuli, Nepal

Structural Analysis and Design Report
Doctors Quarter

Municipality, Karmaiya, Sarlahi

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Ghiyanglekh Sindhuli 10 beded Hospital
Block A+B

(STRUCTURAL ANALYSIS AND DESIGN REPORT)

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1. INTRODUCTION

The basic aim of the structural design is to build a structure, which is safe, fulfilling the intended purpose during its estimated life span, economical in terms of initial and maintenance cost, durable and also maintaining a good aesthetic appearance.

A building is considered to be structurally sound, if the individual elements and the building as a whole satisfy the criteria for strength, stability and serviceability and in seismic areas additional criteria for ductility and energy absorption capabilities. The overall building must be strong enough to transfer all loads through the structure to the ground without collapsing or losing structural integrity by rupture of the material at the critical sections, by transformation of the whole or parts into mechanisms or by instability.

2. SEISMIC VULNERABILITY OF NEPAL

Nepal is located in the boundary of two colliding tectonic plates, namely, the Indian Plate (Indo-Australian Plate) and the Tibetan Plate (Eurasian Plate). The Indian Plate is constantly moving under the Tibetan Plate causing many minor and major earthquakes in this region. As a result, Nepal has witnessed many major as well as minor earthquakes during the past. Records of earthquakes are available in Nepal since 1255 A.D. Those records show that around 18 major earthquakes have shaken Nepal since then. The 1833 A.D. earthquake and 1934 A.D Bihar-Nepal earthquakes and 2015 Gorkha earth quake were the most destructive ones in the history of Nepal.

Thus structures to be built in Nepal need to be suitably designed and detailed, so as to counteract the forces due to earthquakes.

3. PHILISOPHY OF SEISMIC DESIGN

The probability of occurrence of severe earthquakes is much less than that of minor earthquakes at a given site. Many of the structures may never experience severe earthquakes during its lifetime. Construction of any ordinary structures to resist such severe earthquakes without undergoing any damage may not be considered economically feasible, as it may be far cheaper to repair or even rebuild the structure after having severe and strong shaking. On the other hand, structures located in seismic areas experience minor earthquakes rather frequently. Thus, in the event of severe and strong shaking, the structure is allowed to have some damage which may be repairable or even irreparable, but the structure will not be allowed to collapse completely, thereby ensuring the safety of life and the property in the structure. In order that one does not have to undertake frequent repair and retrofitting of the structure, the structure should not have any damage during minor level of shaking. In case of moderate shaking the structure is allowed to have some non-structural damage without endangering life and property within the structure. During such event the level of damage should be such that it can be economically repaired.

The structures are generally designed for much lower seismic forces than what it may actually experience during its life time. Since the structure is expected to undergo damage in the event of a severe shaking, reliance is placed on the inelastic response of the structure beyond yield. Therefore, structures have to be ductile and capable of dissipating energy through inelastic actions. Ductility can be achieved by avoiding brittle modes of failures. Brittle modes of failures include, shear and bond failure. Thus, structures should be designed on Weak beam-Strong column philosophy.

4. BUILDING DESCRIPTION

Type:	Hospital building
Building Typology:	Reinforcement Concrete Frame Building
Form:	
Plan Shape:	Irregular shaped
Plan Configuration:	Irregular
Vertical Configuration:	Irregular
Plinth Area:	658 m^2
Number of Stories	Two Storey
Position of the Building:	Free Standing
Total Height:	**11.7 m** from plinth level
Inter Storey Height:	**3.6** m.
Maximum length of Beam:	4.805 m
Size of Columns:	350 x 350 mm^2
Wall Thickness:	230mm
Floor/Roof structure:	150 mm slab floor
Location of site:	Ghiyanglekh Sindhuli

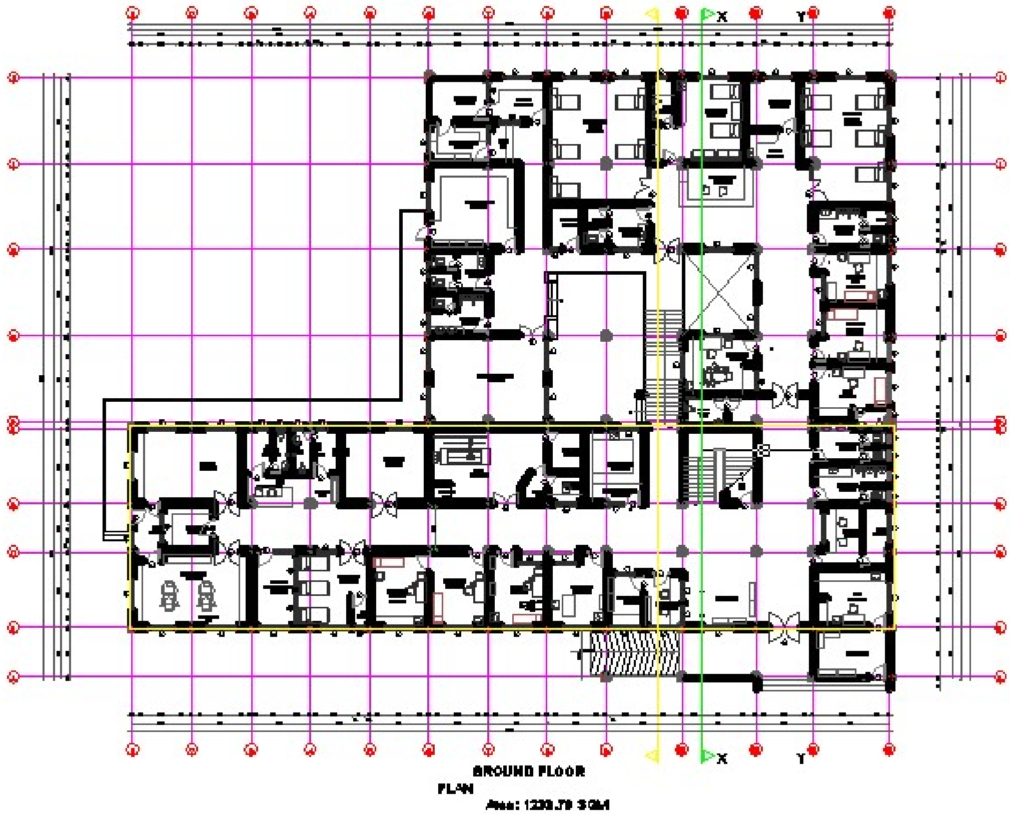


Figure 1: Ground Floor Plan (Refer Drawing for Detail)

5. STRUCTURAL SYSTEM

Material:	Reinforced Cement Concrete
Frame System:	Special Moment Resisting Frame
Floor System:	Two way Solid Slab
Foundation System:	Isolated footing

Material Strengths:

Member	Concrete Grade
Columns	M30
Beams	M20
Slabs	M20
Foundation	M20

Steel

Steel Type	Grade
Thermo mechanically Treated Bar(TMT)	Fe 500

6. LOADS ADOPTED

Load calculation is done using the NBC 102:1994 as reference. At first type of material is selected and value of unit weight of the materials is taken from the above mentioned code. Thickness of the material is selected as per the design requirement. Knowing area, thickness and unit weight of materials, loads on each section is found.

The following are assumed for detail load calculation.

- R.C.C Slab, Beam and Column = 25.0 KN/m^3
- Screed (25mm thick) = 19.2 KN/m^3
- Cement Plaster (20mm thick) = 20.40 KN/m^3
- Marble Dressed = 26.50 KN/m^3
- Telia Brick = 19 KN/m^3

Live Load

Live load for the floor and Roof is taken from IS 875 part 2 as referred by National building code. For Institutional Building, Following load has be taken (Table 1, IS 875 Part 2)

Bedrooms, Wards, Dressing rooms, lounges - 2 KN/m2
Toilet and bath rooms - 2 KN/m2
Corridors, passages, staircases including fire escapes - 4 KN/m2
Balconies - 4 KN/m2
X-Ray rooms, operating rooms, and general stores - 3 KN/m2
Office rooms and OPDs – 2.5 KN/m2
Kitchen, Laundries and laboratories - 3 KN/m2

For Roof Load, Table 2 of IS 875 part 2 has been taken for the estimation

Flat, sloping or curved roof with slopes up to and including 10 degrees
Access not provided except for maintenance – 0.75 KN/m^2

Floor Finish

Floor Finish Load is calculated Simple Marble Finishes. With load calculation

Depth of Finishes = 0.055 m
Marble Dressed = 26.50 KN/m^3
Weight per Square meter = 0.055 * 26.5 = 1.458 KN/m^2 (Assume 1.5 KN/m^2)

Wall Loads

Wall loads are applied on underneath beam if wall is rested on the beam. For partition wall load is applied as the area load intensity. Load intensity is calculated by dividing total weight of partition wall by the area of given slab portion.

7. SEISMIC DESIGN PARAMETERS

The seismic design parameters have been considered in reference with IS1893:2016 and are presented as follows:

Seismic Zone Factor

Seismic Zone	Z
Sindhuli (Zone V)	0.36

Important Factor

Building Occupancy Type	I
Hospital Building	1.5

Structural performance Factor

Response Reduction Factor	R
	5

Site Soil Category

Soil Type	Soft Soil (Type II)

8. PRELIMINARY DESIGN

For the analysis, dead load is also necessary which depends upon the size of member itself. So it is necessary to pre-assume logical size of member which will neither overestimate the load nor under estimate the stiffness of the building. So, the tentative sizes of the structural elements are determined through the preliminary design so that the pre-assumed dimensions may not deviate considerably after analysis thus making the final design both safe and economical. Tentative sizes of various elements have been determined as follows:

Slab:

Preliminary design of slab is done as per the deflection criteria as directed by code Clause 23.2.1 of [IS 456: 2000]. The cover provided is 20 mm and the grade of concrete used in the design is M20.

According to which,

$$\frac{\text{Span}}{\text{Eff. Depth}} \leq (M_{ft} \times M_{fc}) \times \text{Basic Value}$$

Where, the critical span is selected which is the maximum shorter span among the all slab element. This is done to make uniformity in slab thickness. The amount of reinforcement will be varied slab to slab but the thickness will be adopted corresponding to the entire slab.

Beam:

Preliminary design of the beam is done as per the deflection criteria as directed by code Clause 23.2.1 of [IS 456: 2000] and ductility criteria of ACI code. The cover provided is 30 mm and the grade of concrete used in the design is M20.

According to which,

$$\frac{\text{Span}}{\text{Eff. Depth}} \leq (M_{ft} \times M_{fc}) \times \text{Basic Value} \times \text{Correction Factor for span} \times \text{Correction Factor for Flange}$$

But,

According to Ductility code, Spacing of Stirrups in beam should not exceed d/4 or 8 times diameter of minimum size of bar adopted and should not greater than 100mm. So, for considering construction difficulties in actual field, it is logical to use d/4 as spacing as per the construction practice in Nepal.

COLUMN:

Preliminary design of column is done from the assessment of approximate factored gravity loads and live loads coming up to the critical section. To compensate the possible eccentric loading and earthquake loads the size is increased by about 25% in design. For the load acting in the column, live load is decreased according to IS 875: 1978. Initially a rectangular column is adopted in this building project so as to provide internal aesthetics required from architecture point of view but the column size and shape will vary as per the requirement for the analysis, design and aesthetic value. The cover provided is 40 mm and the grade of concrete used in the column design is M25.

9. FINITE ELEMENT MODELING AND ANALYSIS OF BUILDING USING SAP2000 V19

The FE model of building is developed in SAP2000 V22, a general purpose FE analysis and design software. The size of beams and columns as obtained from preliminary analysis are adjusted according to architectural need. Beam and columns are modeled as frame element. Slabs are also modeled as shell element.

Beam and column are assumed to be line element having six degree of freedom at each node and slab is assumed to be shell element having six degree of freedom at each node. Floor diaphragm is used in the structure to reduce degree of freedom to three for each floor level.

Imposed loads have been modeled as uniform distributed loads. Similarly, wall loads are modeled as uniformly distributed line loads. The columns and walls were “fixed” at their base.

The 3D model is assumed to be fixed at tie beam level. Suitable assumptions are made and FE model as shown in Fig 2 is developed.

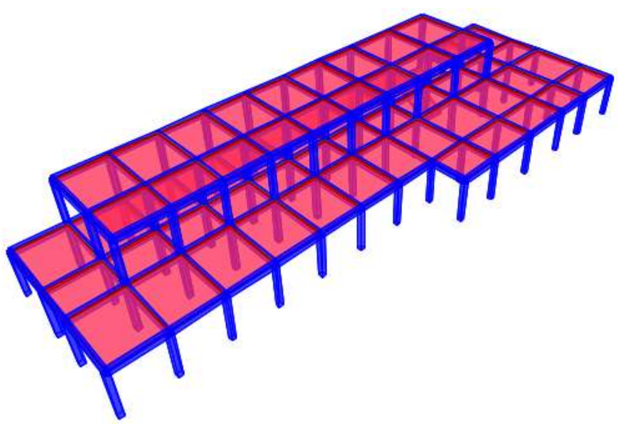


Figure 2: Finite Elemental Modeling in Sap2000 V 22 (A Block)

Loading due to wall, floor finish and live load is as shown in figure below and analysis is done by static method (seismic coefficient method) and Response Spectrum Method. Following forces is observed during Analysis:

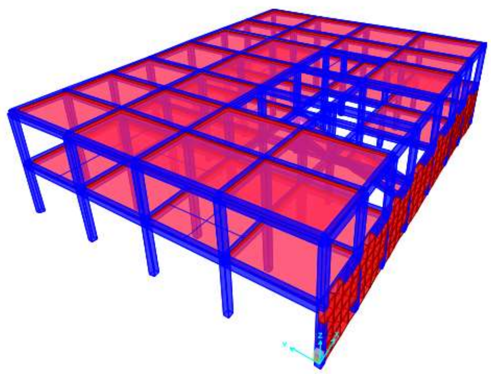


Figure 3: Finite Elemental Modeling in SAP2000 V22 B Block)

9.1 LOADS APPLIED ON BUILDING:

9.1.1 Floor Finish

This load is applied all over the slab. Load application is shown in figure below.

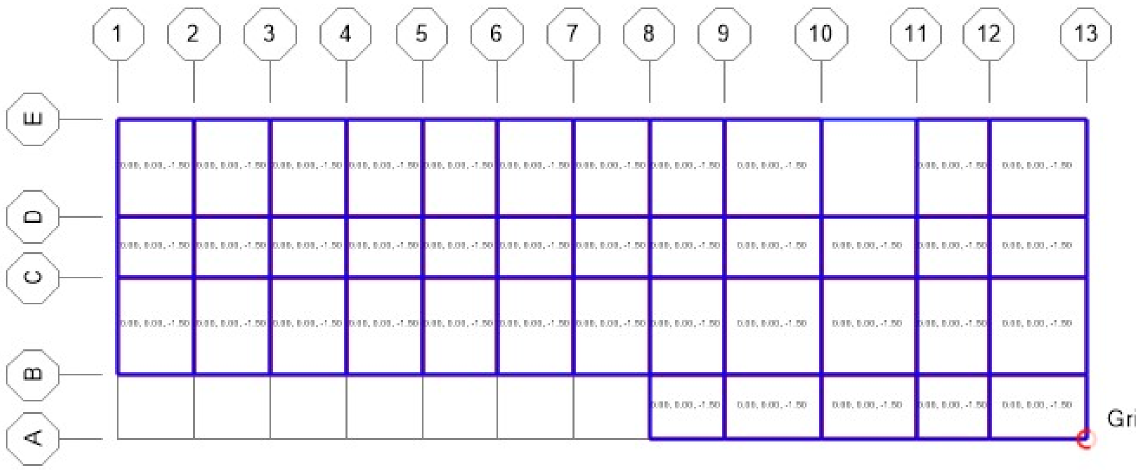


Figure 4: Floor Finish load at First Floor (1.5KN/m^2) (A block)

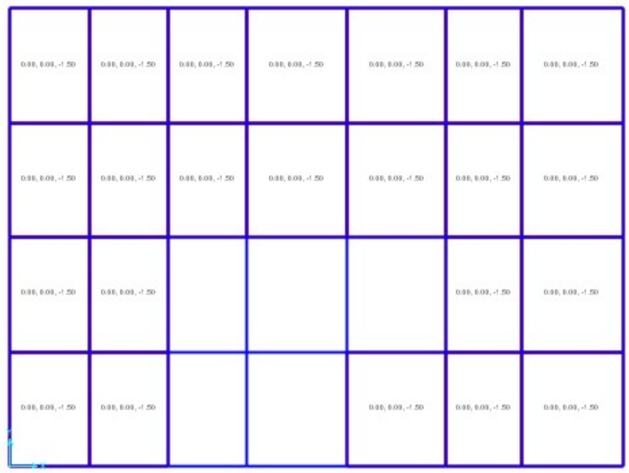


Figure 5: Floor Finish load at First Floor (1.5KN/m2) (B block)

9.1.2 Live Load

Application of live load is shown in figure below.

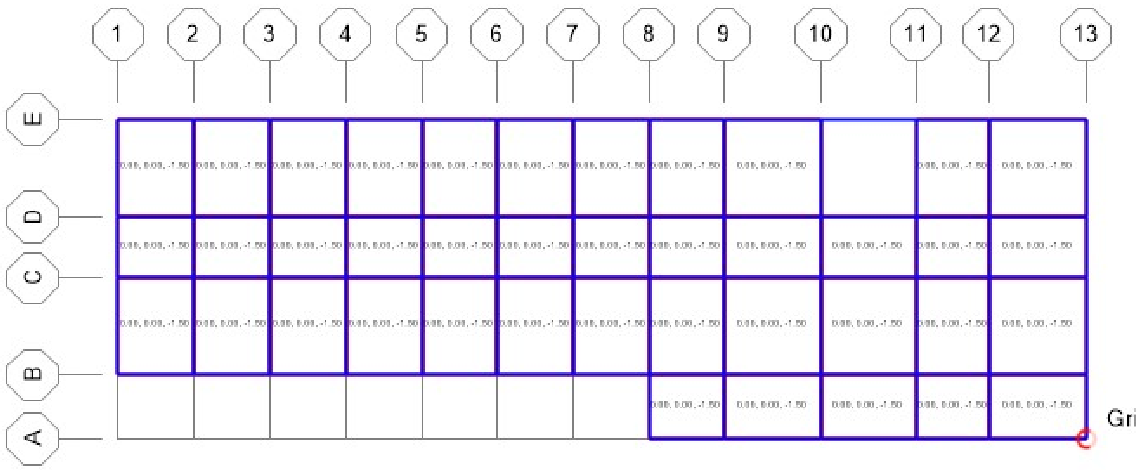


Figure 6: Sample Live Load > 3 KN/m2 (A block)

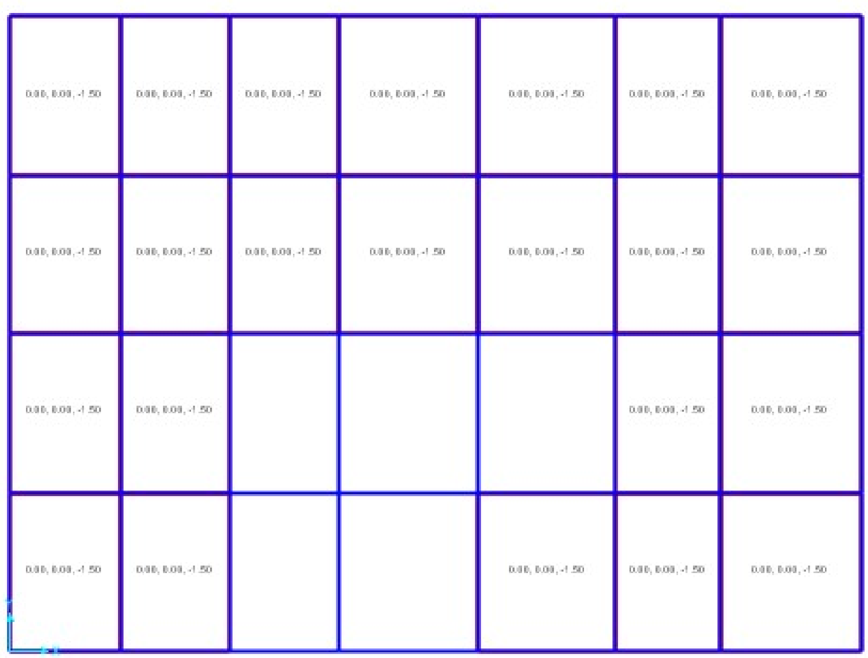


Figure 7: Sample Live Load < 3 KN/m2 (B block)

Please Refer Model Provided along with the Report for Detail

9.1.3 Wall load

Load coming from the weight of wall is applied on the beam underneath the wall. If there is not any beam below the wall, load is applied to nearby beam in the direction of wall. Application of wall load is shown in figure below. Detail Calculation of the wall load is presented in Annex.

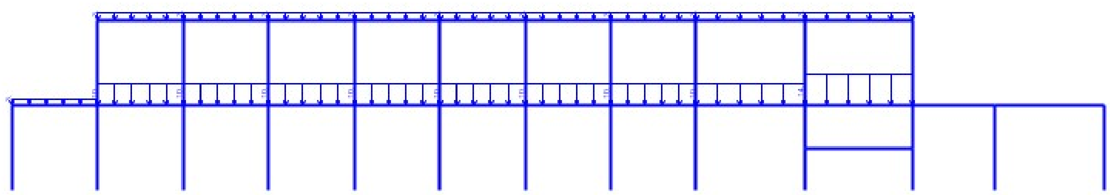


Figure 8: Sample Wall Load (A block)

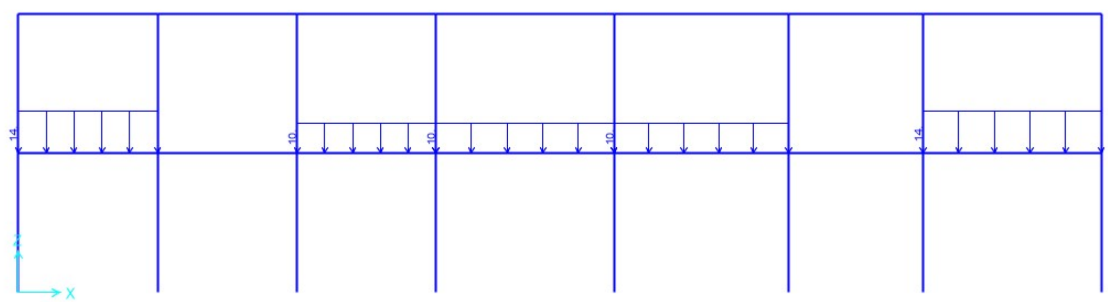


Figure 9: Sample Wall Load (B block)

Please Refer Model Provided along with the Report for Detail

9.2 LATERAL LOAD ESTIMATION ACCORDING TO IS 1893:2016

Lateral loads on the building frames are caused primarily by wind pressure. In addition; earthquake shocks produce horizontal sway, which results in inertia forces acting horizontally on the structure. But in an area like Malunga,Syangja wind load is not so vital so, only the lateral load due to earthquake shock is considered in this case.

9.2.1 A block

For the analysis and design of earthquake action following method has been applied in this building.

Response spectrum method

Following assumptions have been made to estimate the total base shear in the buildings:

Zone factor for Ghiyanglekh Sindhuli according to IS code ,

Z=0.36

Response Reduction Factor = 5 for moment resisting frame.

Importance factor = 1.5

For building with RC frame structures, the empirical relation for time period is given by the relation,

$$T = \frac{0.09 * h}{\sqrt{d}}$$

Direction	Height H (m)	Dimension D	time Period T=0.09 H / $(D)^{0.5}$ (sec)
Y	7.2	13	0.179
X	7.2	46.55	0.094

.

With this fundamental time period in medium soil type-II, a graphical interpolation has been made to calculate
Sa/g = 2.5

TABLE: Base Reactions

OutputCase	CaseType	StepType	GlobalFX	GlobalFY	GlobalFZ
Text	Text	Text	KN	KN	KN
DEAD	LinStatic		-7.862E-12	1.624E-12	6168.991
LIVE<3	LinStatic		0	0	0
FF	LinStatic		-3.34E-12	-2.316E-12	1343.578
WALL	LinStatic		-1.459E-12	4.427E-12	2066.555
PT	LinStatic		-8.566E-13	-5.795E-14	440.099
LIVE>3	LinStatic		-6.018E-12	-3.819E-13	3080.695
EQX	LinStatic		-1517.88	3.774E-11	8.811E-13
EQY	LinStatic		9.364E-11	-1517.88	5.805E-12
rsx	LinRespSpec	Max	1560.561	181.47	6.513
rsy	LinRespSpec	Max	182.351	1560.684	14.599

Auto Seismic - IS 1893:2016

Linear Dynamic analysis (Response Spectrum Analysis)

Response spectrum analysis is done for the building with irregular configuration and much accurate method. Response spectrum function of IS 1893:2016 is used for the response spectrum.

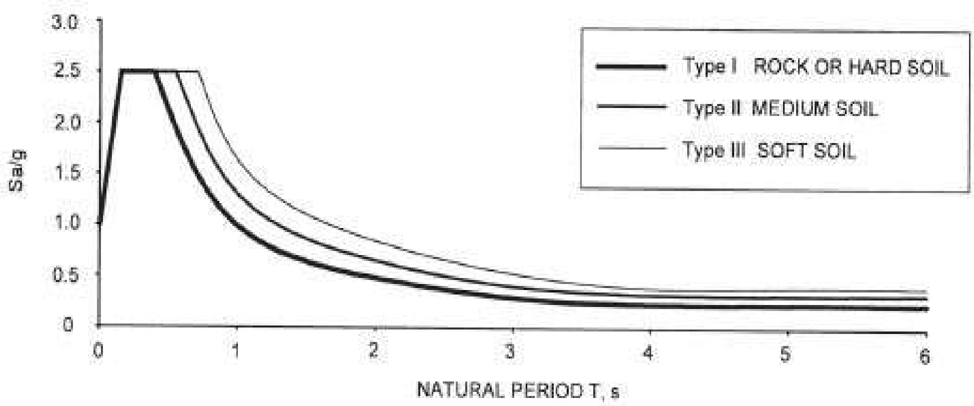


Figure 10 Response Spectrum function used as per IS1893:2016

Base shear due to Response spectrum function must not be less than Base shear calculated liner static method. So following modification factor is used in the response spectrum cases in SAP2000.

|Direction	Symbol	Modification Factor
X	Λx	12.2
Y	Λy	12.2

9.2.2 B block

For the analysis and design of earthquake action following method has been applied in this building.

The Response spectrum method

Following assumptions have been made to estimate the total base shear in the buildings:

Zone factor for Ghiyanglekh Sindhuli according to IS code ,

Z=0.36

Response Reduction Factor = 5 for moment resisting frame.

Importance factor = 1.5

For building with RC frame structures, the empirical relation for time period is given by the relation,

$$T = \frac{0.09 * h}{\sqrt{d}}$$

Direction	Height H (m)	Dimension D	time Period $T=0.09\ H / (D)^{0.5}$ (sec)
X	7.2	28.326	0.140
Y	7.2	21.238	0.121

.

With this fundamental time period in medium soil type-III, a graphical interpolation has been made to calculate

Sa/g = 2.5

Auto Seismic - IS 1893:2016

	A	B	C	D	E	F
1	TABLE: Base Reactions					
2	OutputCase	CaseType	StepType	GlobalFX	GlobalFY	GlobalFZ
3	Text	Text	Text	KN	KN	KN
4	DEAD	LinStatic		-3.563E-12	3.681E-12	7437.875
5	FF	LinStatic		-1.205E-12	4.237E-13	1425.878
6	WALL	LinStatic		-2.014E-12	2.701E-12	2271.982
7	PT	LinStatic		-8.121E-13	-7.974E-13	501.318
8	LIVE>3	LinStatic		-2.08E-12	2.75E-12	3274.997
9	EQX	LinStatic		-1753.306	4.868E-10	0
10	EQY	LinStatic		1.306E-10	-1753.306	0
11	rsx	LinRespSpec	Max	1791.519	143.498	15.898
12	rsy	LinRespSpec	Max	100.849	1791.705	28.043

Linear Dynamic analysis (Response Spectrum Analysis)

Response spectrum analysis is done for the building with irregular configuration and much accurate method. Response spectrum function of IS 1893:2016 is used for the response spectrum.

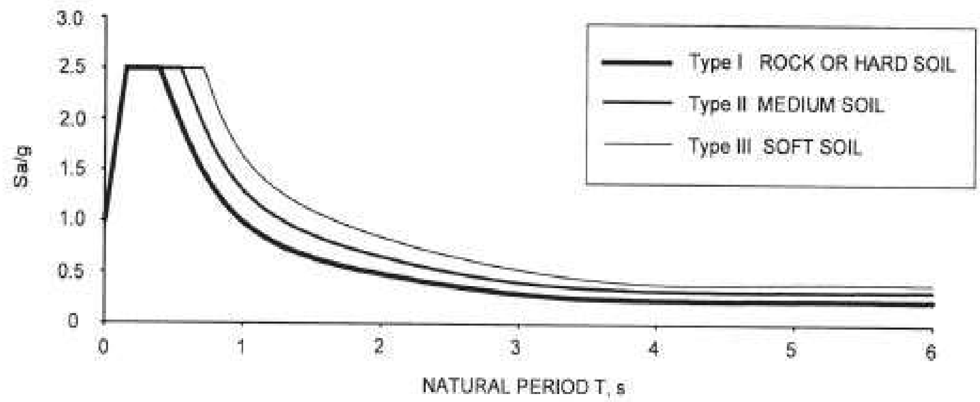


Figure 11 Response Spectrum function used as per IS1893:2016

Base shear due to Response spectrum function must not be less than Base shear calculated liner static method. So following modification factor is used in the response spectrum cases in SAP2000.

|Direction	Symbol	Modification Factor
X	Λx	18.67
Y	Λy	13.3

9.3 LOAD CASES AND COMBINATION

9.3.1 Load Cases

Load cases are the independent loadings for which the structure is explicitly analyzed. Earthquake forces occur in random fashion in all directions. For buildings whose lateral load resisting elements are oriented in two principal directions, it is usually sufficient to analyze in these two principal directions (X – and Y – direction) separately one at a time. Thus, the load cases adopted are as follows:

i. Dead Load (DL)
ii. Live Load (LL)
iii. EQX
iv. EQY
v. RSX
vi. RSY

9.3.2 Load Combinations

Load combinations are the loadings formed by the linear combination of the independent loading conditions. The different load cases have been combined as per IS Code .The load combinations are as follows:

i. 1.5 DL + 1.5 LL
ii. 1.2(DL+LL+- EQ)
iii. 0.9DL+-1.5 EQ

DL= Dead Load

LL= Live load

EQ= Earthquake Load

For the dynamic analysis Earth quake load is replaced by Response spectrum Load RSX and RSY.

9.4 Base Reaction

Base Reactions .Block A					
EQX	LinStatic		-1517.88	3.774E-11	8.811E-13
EQY	LinStatic		9.364E-11	-1517.88	5.805E-12
rsx	LinRespSpec	Max	1560.561	181.47	6.513
rsy	LinRespSpec	Max	182.351	1560.684	14.599

Base reaction Block B					
LIVE>3	LinStatic		-2.08E-12	2.75E-12	3274.997
EQX	LinStatic		-1753.306	4.868E-10	0
EQY	LinStatic		1.306E-10	-1753.306	0
rsx	LinRespSpec	Max	1791.519	143.498	15.898
rsy	LinRespSpec	Max	100.849	1791.705	28.043

9.5 MODAL RESULT

Free vibration analysis was performed to determine the natural periods and mode shapes of the buildings. The number of modes, corresponding natural periods and mass participation ration of the building is tabulated in Tables below.

Table 1: Mode numbers, natural periods and mass participation (A block)

TABLE: Modal Participating Mass Ratios												
OutputCase	StepType	StepNum	Period	UX	UY	UZ	SumUX	SumUY	SumUZ	RX	RY	RZ
Text	Text	Unitless	Sec	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless
MODAL	Mode	1	0.415127	0.0063	0.793	0.000004028	0.0063	0.793	0.000004028	0.02523	0.00013	0.08639
MODAL	Mode	2	0.379284	0.78563	0.01953	0.0000106	0.79193	0.81253	0.00001463	0.00049	0.00305	0.04209
MODAL	Mode	3	0.339885	0.05704	0.04432	0.000004627	0.84897	0.85686	0.00001926	0.00111	0.0000122	0.67878
MODAL	Mode	4	0.20995	0.00867	0.08273	0.00023	0.85764	0.93958	0.00025	0.04388	0.00013	0.11812
MODAL	Mode	5	0.19825	0.04458	0.04635	0.00025	0.90223	0.98593	0.0005	0.05537	0.00318	0.02596
MODAL	Mode	6	0.190794	0.08739	0.00494	0.00002138	0.98962	0.99087	0.00052	0.01034	0.01113	0.03996
MODAL	Mode	7	0.103963	0.00042	0.00016	0.00002032	0.99004	0.99103	0.00054	0.00011	8.645E-07	0.00012
MODAL	Mode	8	0.080387	8.936E-08	5.645E-07	0.06363	0.99004	0.99103	0.06417	0.04075	0.03736	0.000004563
MODAL	Mode	9	0.080048	0.000003219	0.00000683	0.00399	0.99004	0.99104	0.06817	0.00401	0.00271	0.000003552
MODAL	Mode	10	0.07833	0.00001676	0.00000323	0.00864	0.99006	0.99104	0.07681	0.00414	0.00168	0.000002013
MODAL	Mode	11	0.077387	0.00004287	0.00001712	0.02804	0.9901	0.99106	0.10485	0.00356	0.08202	0.00003313
MODAL	Mode	12	0.076563	0.000001103	0.00002042	0.00611	0.9901	0.99108	0.11096	0.00014	0.00128	0.000004923

TABLE: Modal Participating Mass Ratios													
OutputCase	tepTyp	tepNum	Period	UX	UY	UZ	SumUX	SumUY	SumUZ	RX	RY	RZ	
Text	Text	Unitless	Sec	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	
MODAL	Mode	1	0.491724	0.46426	0.0017	0.000007326	0.46426	0.0017	0.000007326	0.00007054	0.00357	0.44476	
MODAL	Mode	2	0.394528	0.0009	0.71361	0.000006215	0.46516	0.71531	0.00001354	0.02111	0.00001952	0.00157	
MODAL	Mode	3	0.287711	0.19203	0.00038	0.000001225	0.65718	0.71569	0.00001477	0.0000487	0.01298	0.23153	
MODAL	Mode	4	0.195311	0.05986	0.00183	0.000003439	0.71704	0.71752	0.00001821	0.00024	0.01481	0.02805	
MODAL	Mode	5	0.165034	0.00000794	0.23074	0.00027	0.71705	0.94827	0.00029	0.03862	3.737E-07	0.00074	
MODAL	Mode	6	0.111209	0.11834	0.0047	0.00092	0.83539	0.95296	0.00121	0.00137	0.00183	0.12908	
MODAL	Mode	7	0.108077	0.00436	0.00169	0.01515	0.83976	0.95465	0.01636	0.01219	0.00002148	0.00655	
MODAL	Mode	8	0.102114	0.00047	0.0005	0.00006005	0.84023	0.95516	0.01642	0.00478	0.0000291	0.00082	
MODAL	Mode	9	0.099775	0.00063	0.000003738	0.00009075	0.84085	0.95516	0.01651	0.00447	0.00139	0.00138	
MODAL	Mode	10	0.09761	3.846E-07	0.00028	0.0081	0.84086	0.95544	0.02461	0.02736	0.00002539	3.691E-07	
MODAL	Mode	11	0.094582	0.000002202	0.00005766	0.00017	0.84086	0.9555	0.02478	0.03023	0.00151	0.00002454	
MODAL	Mode	12	0.093807	0.00006054	0.00012	0.00371	0.84092	0.95562	0.0285	0.0071	0.00025	0.00012	

Table 2: Mode numbers, natural periods and mass participation (B block)

9.6 DRIFT OF THE BUILDING

The deformation of the buildings is also determined and found that the drift limit is compliance with the provision of IS 1893:2016. The story drift of the building along x and y-direction is tabulated below.

Table 3: Floor displacement and inter storey drift (A block)

Table: Floor Displacement and Inter storey Drift							
Story	Direction	Inter Story Height	Ux	Uy	Design Drift	Drift Ratio	Remarks
		mm				% <	0.40%
Second	EQX	3600	8.681		4.997	0.139	OK
First	EQX	3600	3.684		3.486	0.102	OK
Second	EQY	3600		12.055	5.438	0.151	OK
First	EQY	3600		6.617	6.617	0..184	OK

The maximum story drift is 0.103 % which is less than permissible value (0.4%) prescribed by the code.

Table 4: Floor displacement and inter storey drift (B block)

Table: Floor Displacement and Inter storey Drift							
Story	Direction	Inter Story Height	Ux	Uy	Design Drift	Drift Ratio	Remarks
		mm				% <	0.40%
Second	EQX	3600	7.6		5.76	0.16	OK
First	EQX	3600	1.84		1.84	0.051	OK
Second	EQY	3600		9.55	6.32	0.176	OK
First	EQY	3600		3.23	3.23	0.09	OK

9.7 CHECK FOR TORSION

Table 5: Torsion check for building (A block)

Table: Check For Torsion									
Story	Direction	Displacement of A mm		Displacement of B mm		Average Displacement	Maximum Displacement	1.2 Average Displacement	Remarks
		Ux	Uy	Ux	Uy				
1	EQX	4.966		3.765		4.3655	4.966	5.2386	Regular
2	EQX	2.873		1.751		2.312	2.873	2.7744	Irregular
1	EQY		2.634		2.167	2.4005	2.634	2.8806	Regular
2	EQY		6.572		5.948	6.26	6.572	7.512	Regular

Table 6: Torsion check for building (B block)

Table: Check For Torsion									
Story	Direction	Displacement of A mm		Displacement of B mm		Average Displacement	Maximum Displacement	1.2 Average Displacement	Remarks
		Ux	Uy	Ux	Uy				
1	EQX	2.218		1.727		1.9725	2.218	2.367	Regular
2	EQX	5.111		4.536		4.8235	5.111	5.7882	Regular
1	EQY		2.434		2.283	2.3585	2.434	2.8302	Regular
2	EQY		6.264		5.483	5.8735	6.264	7.0482	Regular

To check and balance torsion, Response Spectrum analysis has been carried out.

10. DESIGN OF STRUCTURL MEMBERS

10.1 Design of slab

The slabs are kept in such a way that ly/lx is kept less than 2 such that it can be designed as two way slab. The slab is designed using SAP2000 V22 and checked manually on excel sheet based on IS 456:2000 and is presented in Annex.

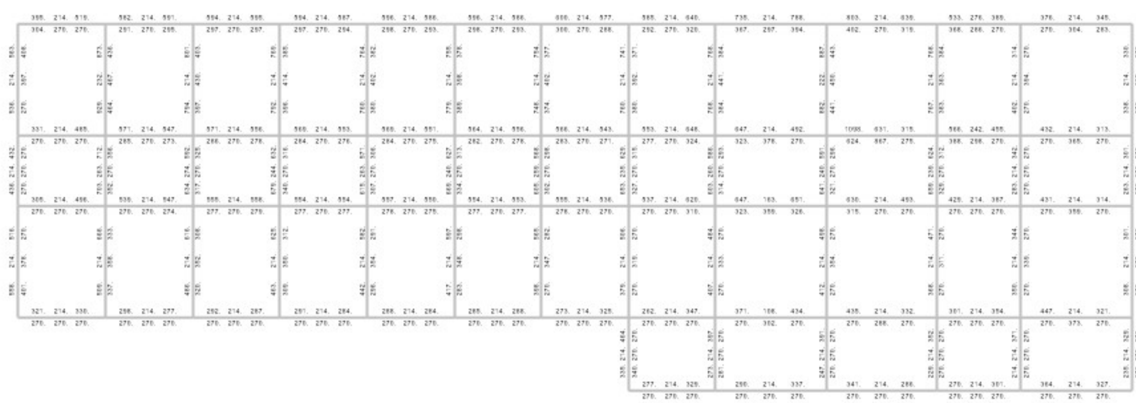
10.2 Design of Beam

The beams are designed with the help of SAP2000 V22 and checked manually. The calculation of reinforcement on typical section of beam is obtained by SAP2000 V22 as shown below in Fig.

Figure 12: Sample Reinforcement at First floor beam (A block)

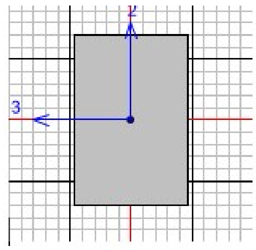
Please Refer Model Provided along with the Report for Detail

The sample design of beam at first floor grid is presented below:



SAP2000 Concrete Frame Design

IS 456:2000 + IS 13920:2016 Beam Section Design



Units KN, m, C

```
Indian IS 456-2000 BEAM SECTION DESIGN  Type: Ductile Frame  Units: KN, m, C  (Summary)

L=3.584
Element     : 483            D=0.45          B=0.3           bf=0.3
Station Loc : 0.             ds=0.           dct=0.03        dcb=0.03
Section ID  : BEAM300X450    E=22360680.     fc=20000.       Lt.Wt. Fac.=1.
Combo ID    : DCON8          fy=500000.      fys=500000.

Gamma(Concrete): 1.5
Gamma(Steel)   : 1.15


Factored Forces and Moments
           Factored    Factored    Factored    Factored
                Mu3          Tu         Vu2          Pu
            -89.676       4.193      81.263     -22.929

Design Moments, Mu3
           Factored     Torsion    Positive    Negative
             Moment          Mt      Moment      Moment
            -89.676       6.166          0.     -95.842

Longitudinal Reinforcement for Moment and Torsion (Mu3, Tu)
                       Required     +Moment     -Moment     Minimum
                          Rebar       Rebar       Rebar       Rebar
   Top    (+2 Axis)   5.965E-04          0.   5.965E-04   2.142E-04
   Bottom (-2 Axis)   2.982E-04          0.          0.   2.982E-04
```

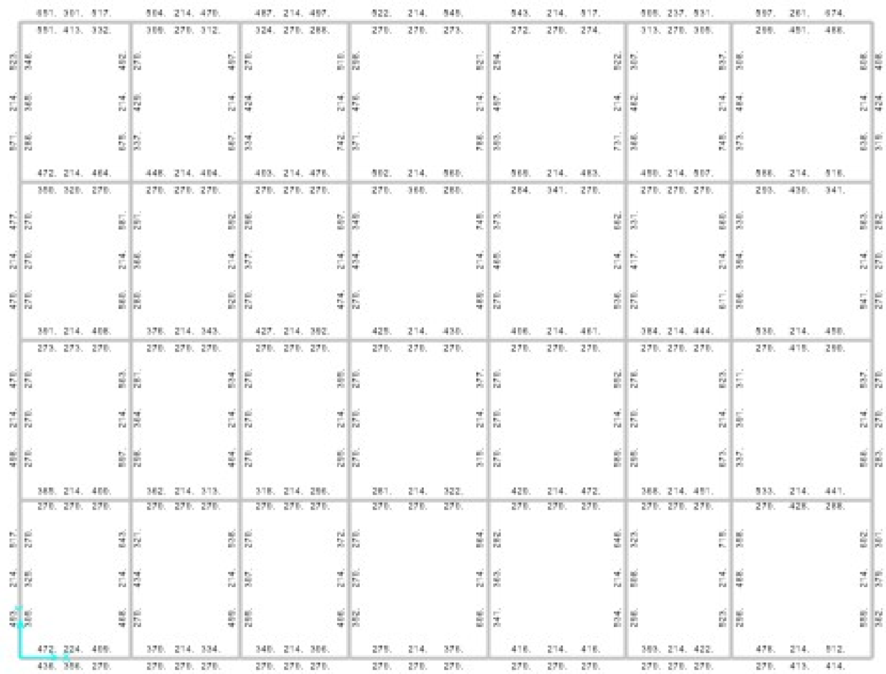


Figure 13: Sample Reinforcement at First floor beam (B block)


```
ndian IS 456-2000 BEAM SECTION DESIGN  Type: Ductile Frame  Units: KN, m, C  (Flexural Details)

=3.583
lement      : 204            D=0.45          B=0.3           bf=0.3
tation Loc  : 3.583          ds=0.           dct=0.03        dcb=0.03
ection ID   : BEAM300X450    E=22360680.     fc=20000.       Lt.Wt. Fac.=1.
ombo ID     : DCON17         fy=500000.      fys=500000.

amma(Concrete): 1.5
amma(Steel)   : 1.15


ONGITUDINAL REINFORCEMENT FOR MOMENT AND TORSION, (Mu3, Tu)
                      Required  +veMoment  -veMoment RegularMin SeismicMin
                         Rebar      Rebar      Rebar      Rebar      Rebar
  Top    (+2 Axis)   4.758E-04         0.  4.758E-04  2.142E-04  2.142E-04
  Bottom (-2 Axis)   2.705E-04  3.595E-05         0.  2.705E-04  2.705E-04

actored Forces and Moments
            Factored    Factored     Torsion
                 Mu3          Tu          Mt
             -77.257       0.887       1.304

esign Moments, Mu3
              Design      Design
           +veMoment   -veMoment
               6.517     -78.561
```

10.3 Design of Column

The rectangular columns are designed with the help of SAP2000 V22 and checked manually. Calculation of longitudinal reinforcement of typical elements is shown below in Fig. below. The method carried out during the structural analysis is verified with other possible methods. There is not significant change in the design values. The interaction curve provided in literature is then used to design these columns.

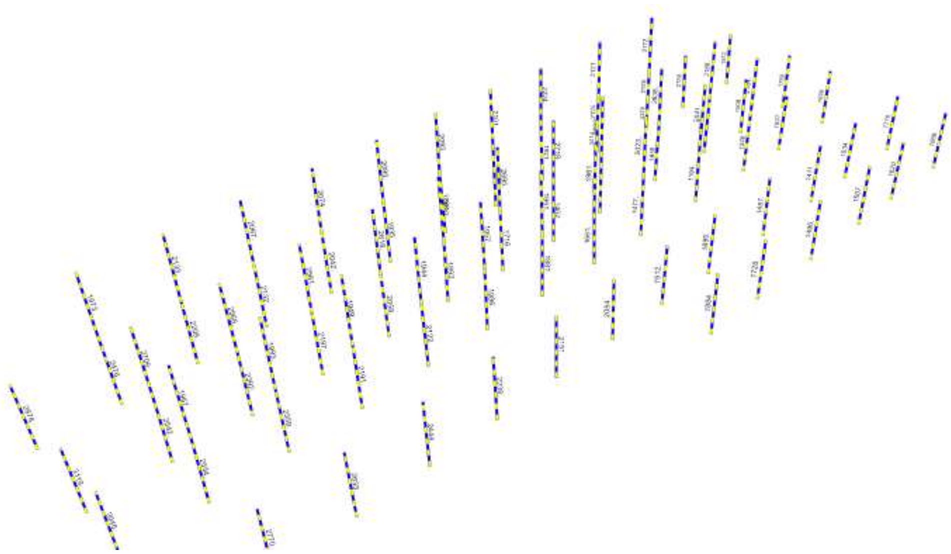
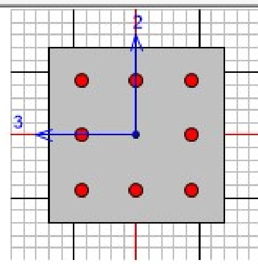


Figure 14 : Column Reinforcement in A block (Columns only shown for clarity)

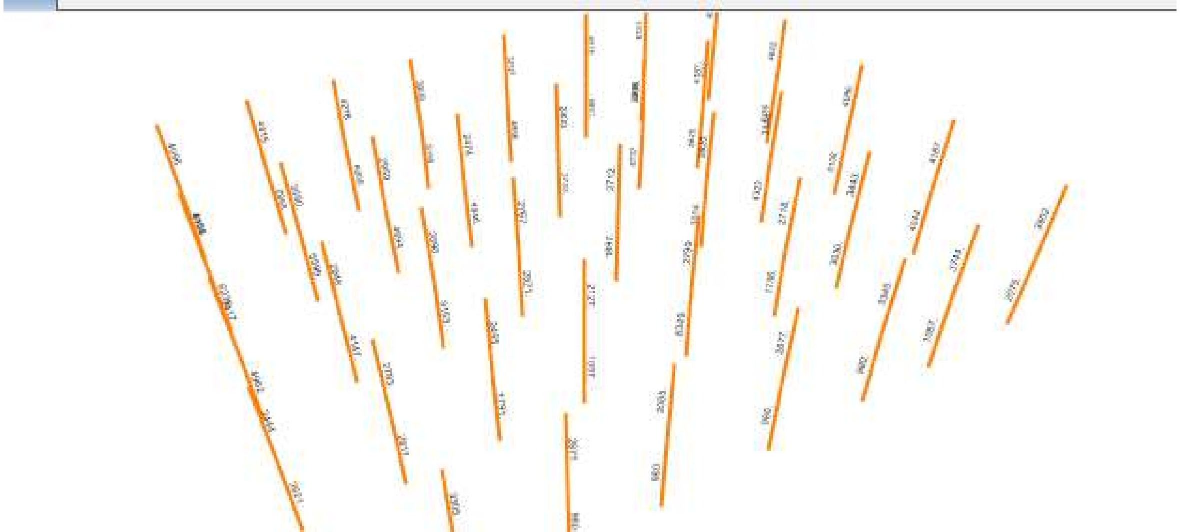
Please Refer Model Provided along with the Report for Detail. Sample design of column of ground floor at grid A1 is shown below:

Units KN, m, C

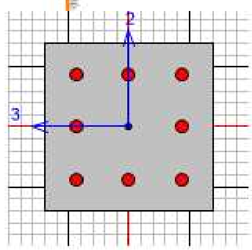



```
Indian IS 456-2000 COLUMN SECTION DESIGN  Type: Ductile Frame  Units: KN, m, C  (Flexural Details)

L=3.6
Element      : 305                B=0.35          D=0.35          dc=0.064
Station Loc  : 0.                 E=22360680.     fc=20000.       Lt.Wt. Fac.=1.
Section ID   : COL350X350         fy=500000.      fys=500000.
Combo ID     : DCON20             RLLF=1.

Gamma(Concrete): 1.5
Gamma(Steel)   : 1.15


AXIAL FORCE & BIAXIAL MOMENT DESIGN FOR Pu, Mu2, Mu3
                         Rebar      Rebar     Design     Design     Design
                          Area          %         Pu        Mu2        Mu3
                         0.002      1.926    131.986    107.138     -8.034

Factored Biaxial Moments
                      Non-Sway       Sway   Factored
                           Mns         Ms         Mu
   Major Bending(M3)    -0.593     -7.441     -8.034
   Minor Bending(M2)      3.32    103.818    107.138

Slenderness Effects (IS 39.7.1) and Minimum Biaxial Moments (IS 39.2, 25.4)
                     EndMoment  EndMoment    Initial       k*Ma    Minimum    Minimum
                           Mu1        Mu2     Moment     Moment     Moment Eccentrcty
   Major Bending(M3)    -8.034     -5.932     -7.193         0.       2.64       0.02
   Minor Bending(M2)   107.138     85.751     98.583         0.       2.64       0.02
```

Figure 15: Column Reinforcement in B block (Columns only shown for clarity)



Units KN, m, C



Indian IS 456-2000 COLUMN SECTION DESIGN Type: Ductile Frame Units: KN, m, C (Flexural Details)

L=3.6			
Element : 16	B=0.35	D=0.35	dc=0.064
Station Loc : 0.	E=22360680.	fc=20000.	Lt.Wt. Fac.=1.
Section ID : COL350X350	fy=500000.	fys=500000.	
Combo ID : DCON19	RLLF=1.		

Gamma(Concrete): 1.5
Gamma(Steel) : 1.15

AXIAL FORCE & BIAXIAL MOMENT DESIGN FOR Pu, Mu2, Mu3

Rebar Area	Rebar %	Design Pu	Design Mu2	Design Mu3
0.002	1.694	-21.915	-87.498	1.83

Factored Biaxial Moments

	Non-Sway Mns	Sway Ms	Factored Mu
Major Bending(M3)	0.211	1.619	1.83
Minor Bending(M2)	-1.824	-85.674	-87.498

Slenderness Effects (IS 39.7.1) and Minimum Biaxial Moments (IS 39.2, 25.4)

	EndMoment Mu1	EndMoment Mu2	Initial Moment	k*Ma Moment	Minimum Moment	Minimum Eccentrcty
Major Bending(M3)	1.83	20.069	12.773	0.	0.438	0.02
Minor Bending(M2)	-87.498	-40.809	-68.822	0.	0.438	0.02

10.4 Design of foundation

The foundations used in the building are of isolated type as per the requirements. The depth of the footing is governed by one way and two way shear (punching shear). The soil type is assumed to be of medium type. So the allowable bearing capacity of soil is taken from the soil test report. Bearing capacity of the isolated footing is at the depth of 2 m.

Allowable bearing capacity = 225 KN/m2

The design of isolated footing has been carried out manually as per IS 456 2000 and is presented in Annex.

10.5 Design of staircase

The staircase used in the building is of Straight flight and dog legged type. The design of staircase is done manually using IS 456 2000 as presented in Annex.

11. CONCLUDING REMARKS

Reinforced concrete construction is common all over the world. It is used extensively for construction of variety of structures such as buildings, bridges, dams, water tanks, stadium, towers, chimneys, tunnels and so on.

Experiences from past earthquakes and extensive laboratory works have shown that a well-designed and detailed reinforced concrete structure is suitable for earthquake resistant structure. Ductility and strength required to resist major earthquake can be achieved by following the recommendations made in the standard codes of practice for earthquake resistant design.

Detailing of steel reinforcement is an important aspect of structural design. Poor reinforcement detailing can lead to structural failures. Detailing plays an important role in seismic resistant design. In seismic resistant design, actual forces experienced by the structure are reduced and reliance is placed on the ductility of the structure. And, ductility can be achieved by proper detailing only. Thus, in addition to design, attention should be paid on amount, location and arrangement of reinforcement to achieve ductility as well as strength.

Design and construction of the structure are inter – related jobs. A building behaves in a manner how it has been built rather than what the intensions is during designing. A large percentage of structural failures are attributed due to poor quality of construction. Therefore, quality assurance is needed in both design and construction.

In earthquake resistant construction quality of materials and workmanship plays a very important role. It has been observed that damages during earthquakes are largely dependent on the quality and workmanship. Hence, quality assurance is the most important factor in the good seismic behavior of the structure.

The strap beam has to be constructed at block B below shear wall must be associated with monolithic and ductile performances with SMRF type.

The straight flight of staircase may belinked up to the columns by inclined beam strut

12. REFERENCE CODE

NBC 110: 1994	Plain and Reinforced Concrete
NBC 102: 1994	Unit Weights of Materials
NBC 103: 1994	Occupancy Load (Imposed Load)
NBC 104: 1994	Wind Load
NBC105: 1994	Seismic Design of Buildings in Nepal
NS: 501-2058	Code of Practice for Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces
SP: 16-1980	Design Aids for Reinforced Concrete to IS: 456-1978
SP: 34-1987	Handbook on Concrete Reinforcement Detailing
IS: 456-2000	Plain and reinforced concrete code
IS: 1893-2002	Earthquake resistant design of structure
IS: 13920	Ductility code

ANNEX

Annex 1: Column Detailing

Grade of concrete : M30			**Grade of steel : Fe500**	
Column ID	Size (mm) (Square)	Lower Ground Floor	Ground floor	First Floor
Block A and B	350	8-25 Φ	4-25 Φ + 4-20 Φ	4-25 Φ + 4-20Φ
Ramp Columns	400	4-25 Φ + 8-20 Φ		

Provide 2-legged Lateral ties 10mm Φ @ 100 mm c/c at h/4 from beam connection and 10mm Φ @ 150 mm c/c at center.

Also Provide Lateral ties 10mm Φ @ 100 mm c/c at lap.

Annex 3 Beam Detailing

Grade of concrete : M20	**Grade of steel : Fe500**

First floor beam (450x300)						
grid line	Left		Mid		Right	
	Top	Bottom	Top	Bottom	Top	Bottom
X-beam						
As per fig	4-20(Th) + 3- 20Φ(Ex)	6-20Φ	4-20Φ(Th)	6-20(Th)	4-20(Th) + 3- 20Φ(Ex)	6-20Φ
As per fig	4-20(Th) + 2- 20Φ(Ex)	5-20Φ	4-20Φ(Th)	5-20(Th)	4-20(Th) + 2- 20Φ(Ex)	5-20Φ
Y-beam						
As per fig	4-20(Th) + 3- 20Φ(Ex)	6-20Φ	4-20Φ(Th)	6-20(Th)	4-20(Th) + 3- 20Φ(Ex)	6-20Φ
As per fig	4-20(Th) + 2- 20Φ(Ex)	5-20Φ	4-20Φ(Th)	5-20(Th)	4-20(Th) + 2- 20Φ(Ex)	5-20Φ

Second floor beam (400 x 600)						
grid line	Left		Mid		Right	
	Top	Bottom	Top	Bottom	Top	Bottom
X-beam						
As per fig	4-20(Th) + 2-20Φ(Ex)	5-20Φ	4-20Φ(Th)	5-20(Th)	4-20(Th) + 2-20Φ(Ex)	5-20Φ
As per fig	4-20(Th) + 2-20Φ(Ex)	5-20Φ	4-20Φ(Th)	5-20(Th)	4-20(Th) + 2-20Φ(Ex)	5-20Φ
Y-beam						
As per fig	4-20(Th) + 3-20Φ(Ex)	6-20Φ	4-20Φ(Th)	6-20(Th)	4-20(Th) + 3-20Φ(Ex)	6-20Φ
As per fig	4-20(Th) + 2-20Φ(Ex)	5-20Φ	4-20Φ(Th)	5-20(Th)	4-20(Th) + 2-20Φ(Ex)	5-20Φ

First floor beam (450 x 300)

grid line	Left		Mid		Right	
	Top	Bottom	Top	Bottom	Top	Bottom
All Beams	4-20(Th) + 2- 20Φ(Ex)	5-20Φ	4-20Φ(Th)	5-20(Th)	4-20(Th) + 2- 20Φ(Ex)	5-20Φ

Provide 2-legged vertical stirrup 10mm Φ 100 mm c/c at 2D- from support and 10mm Φ @ 150 mm c/c at center.

Also provide 2-legged vertical stirrup 10mm Φ @ 100 mm c/c at lap

Annex 4: Design of Foundation

The foundation is of isolated and combined type. The footing has been designed manually as per IS 456 2000. Sample design calculation for footing type F1 is shown below:

see Pdf attached

Similarly calculations were done for other footing types and shown in drawing.

Annex 5: Design of Slab

See Pdf attached

Annex 6: Design of Staircase

See Pdf attached

Annex 7: Design of Shear wall with strap beam

See Pdf attached